

CLAIMS:

1. A system for generating an ion beam (475 or 240) comprising an ion source (400 or 10) in combination with an extraction electrode (405 or 220) and a reactive gas cleaning system (455, 430),

the ion source comprising an ionization chamber (500) connected to a high voltage power supply and having an inlet (441, 440 or 435) for gaseous or vaporized feed materials, an energizeable ionizing system for ionizing the feed material within the ionization chamber and an extraction aperture (304) that communicates with a vacuum housing (410 or 209), the vacuum housing evacuated by a vacuum pumping system (420),

the extraction electrode (405 or 220) disposed in the vacuum housing outside of the ionization chamber, aligned with the extraction aperture (504) of the ionization chamber and adapted to be maintained at a voltage below that of the ionization chamber to extract ions through the aperture from within the ionization chamber,

and the reactive gas cleaning system (455, 430) operable when the ionization chamber and ionizing system are de-energized to provide a flow of reactive gas through the ionization chamber (500) and through the ion extraction aperture (504) to react with and remove deposits on at least some of the surfaces of the ion generating system.

2. The system for generating an ion beam of claim 1 constructed for use in implanting ions in semiconductor wafers, the ionization chamber (500) having a volume less than about 100ml and an internal surface area of less than about 200cm².

3. The system for generating an ion beam of claim 1 or 2 constructed to produce a flow of the reactive gas into the ionization chamber at a flow rate of less than about 2 Standard Liters Per Minute.

4. The system for generating an ion beam of any of the foregoing claims in which the extraction electrode (405 or 220) is constructed to produce a beam of accelerated ions suitable for transport to a point of utilization.

5. The system for generating an ion beam of any of the foregoing claims in which the extraction electrode (405 or 220) is located within a path of reactive gas moving from the extraction aperture (504) to the vacuum pumping system so that the extraction electrode is cleaned by the reactive gas.
6. The system for generating an ion beam of any of the foregoing claims in which the extraction electrode (405 or 220) is associated with a heater (720, 730, 820) to maintain the electrode at elevated temperature during extraction by the extraction electrode of ions produced in the ionization chamber, e.g. above the condensation temperature, below the disassociation temperature of solid-derived, thermally sensitive vapors.
7. The system of any of the foregoing claims 1-5 in which the extraction electrode (405; 220) is associated with a cooling device (512, 522), e.g. when the electrode is formed of temperature sensitive material and is used with a hot ion source.
8. The system for generating an ion beam of any of the foregoing claims in which the extraction electrode has a smooth, featureless aspect.
9. The system for generating an ion beam of any of the foregoing claims in which the reactive gas cleaning system (455, 430) comprises a plasma chamber, the plasma chamber arranged to receive a feed gas capable of being disassociated by plasma to produce a flow of reactive gas through a chamber outlet (456), and a conduit (430) for transporting the reactive gas to the ionization chamber (500).
10. The system for generating an ion beam of claim 9 in which the plasma chamber (500) is constructed and arranged to receive and disassociate a compound capable of being disassociated to atomic fluorine, for instance NF_3 , C_3F_8 or CF_4 .
11. The system for generating an ion beam of claim 9 or 10 in which the reactive gas cleaning system is constructed and arranged to share a service facility (S) associated with the ion source (400 or 10).

12. The system for generating an ion beam of claim 9 or 10 constructed to direct an ion beam through a mass analyzer (230), in which the reactive gas cleaning system is constructed and arranged to share a service facility (S) with the mass analyzer.
13. The system for generating an ion beam of any of the foregoing claims 1-8 in which the reactive gas cleaning system comprises a conduit (430A) from a container of pressurized reactive gas, for instance C1F_3 .
14. The system for generating an ion beam of any of the foregoing claims in combination with an end-point detection system (470, RGA, FTIR, TD) adapted to at least assist in detecting substantial completion of reaction of the reactive gas with contamination on a surface of the system for generating an ion beam.
15. The system for generating an ion beam of claim 14 in which the end point detection system comprises an analysis system (for instance, RGA or FTIR) for the chemical makeup of gas that has been exposed to said surface during operation of the reactive gas cleaning system.
16. The system for generating an ion beam of claim 14 or 15 including a temperature detector (TD) arranged to detect substantial termination of an exothermic reaction of the reactive gas with contamination on a surface of the system.
17. The system for generating an ion beam of any of the foregoing claims in which the energizeable ionizing system includes a component within or in communication with the ionization chamber (500) that is susceptible to harm by the reactive gas and means are provided to shield the component from reactive gas flowing through the system.
18. The system for generating an ion beam of claim 17 in which the means comprises an arrangement for producing a flow of inert gas, such as argon, past the component.

19. The system for generating an ion beam of claim 17 or 18 in which the means comprises a shield member that is impermeable to the reactive gas.
20. The system for generating an ion beam of any of the foregoing claims constructed to operate with reactive halogen gas as the reactive gas and the extraction electrode (405 or 220) and associated parts comprise aluminum (Al) or alumina (Al_2O_3).
21. The system for generating an ion beam of any of the foregoing claims in which the ion source (400 or 10) is constructed to produce ions within the ionization chamber (500) via an arc-discharge, an RF field, a microwave field or an electron beam.
22. The system for generating an ion beam of any of the foregoing claims associated with a vaporizer (28, 445) of condensable solid feed material for producing feed vapor to the ionization chamber.
23. The system for generating an ion beam of any of the foregoing claims in which the ion source is constructed to vaporize feed material capable of producing cluster or molecular ions, and the ionization system is constructed to ionize the material to form cluster or molecular ions for implantation.
24. The system for generating an ion beam of any of the foregoing claims in which the vacuum housing (410 or 209) is associated with a pumping system (420) comprising a high vacuum pump (421) capable of producing high vacuum and a backing pump (422) capable of producing rough vacuum, the high vacuum pump (421) operable during operation of the ion source (400 or 10), and being capable of being isolated from the vacuum housing during operation of the reactive cleaning system, the backing pump (422) operable during operation of the reactive gas cleaning system.
25. The system for generating an ion beam according to any of the foregoing claims associated with an ion implantation apparatus, the apparatus constructed to transport ions

following the extraction electrode (405 or 220) to an implantation station (312, 314, FIG. 16) within a vacuum chamber (330).

26. The system for generating an ion beam of claim 25 including an isolation valve (425 or 200) for isolating the implantation station (312) from the ionization chamber (500) and the extraction electrode (405 or 220) during operation of the reactive gas cleaning system.

27. The system for generating an ion beam of any of the foregoing claims in which the ion source is constructed and adapted to generate dopant ions for semiconductor processing, and the reactive gas cleaning system (455, 430) is adapted to deliver fluorine, F, or chlorine, Cl, ions to the ionization chamber (500) or the extraction electrode (405 or 220) for cleaning deposits from a surface.

28. The system for generating an ion beam of any of the foregoing claims in which said ion source (400 or 10) is adapted to be temperature controlled to a given temperature.

29. The system for generating an ion beam of any of the foregoing claims in which said ion source (400 or 10) is adapted to generate a boron-containing ion beam.

30. The system for generating an ion beam of claim 29 adapted to generate said boron-containing ion beam by feeding vaporized borohydride material into said ion source (400 or 10).

31. The system for generating an ion beam of claim 30 in which said borohydride material is decaborane, $B_{10}H_{14}$.

32. The system for generating an ion beam of claim 30 in which said borohydride material is octadecaborane, $B_{18}H_{22}$.

33. The system for generating an ion beam of any of the claims 1-28 in which said ion source (400 or 10) is adapted to generate arsenic-containing ion beams.

34. The system for generating an ion beam of any of the claims 1-28 in which said ion source (400 or 10) is adapted to generate phosphorus-containing ion beams.
35. The system for generating an ion beam of any of the foregoing claims in which the ionization chamber (500) of said ion source comprises aluminum.
36. The system for generating an ion beam of any of the foregoing claims in which the ionization chamber (500) of said ion source or said extraction electrode comprises a material resistant to attack by halogen gases such as fluorine, F.
37. A method of *in-situ* cleaning with the system of any of the foregoing claims, or of an ion source associated with an ion implanter, in which reactive halogen gas is flowed into an ion source (400 or 10) while the ion source is de-energized and under vacuum.
38. The method of claim 37 in which the reactive halogen gas is fluorine, F.
39. The method of claim 37 in which the reactive halogen gas is chlorine, Cl.
40. The method of claim 37 in which the fluorine gas is introduced into the ion source from a remote plasma source.
41. The method of claim 40 in which the fluorine gas is produced in the remote plasma source by an NF_3 plasma.
42. The method of claim 40 in which the fluorine gas is produced in the remote plasma source by a C_3F_8 or CF_4 plasma.
43. The method of claim 37 in which the reactive halogen gas is ClF_3 .
44. The method of any of the claims 37-43 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized decaborane, $\text{B}_{10}\text{H}_{14}$.

45. The method of any of the claims 37-43 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized octadecaborane, $B_{18}H_{22}$.

46. The method of any of the claims 37-43 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized arsenic-containing compounds, such as arsine, AsH_3 , or elemental arsenic, As.

47. The method of any of the claims 37-43 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized phosphorus-containing compounds, such as elemental phosphorus, P, or phosphine, PH_3 .

48. The method of any of the claims 37-43 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized antimony-containing compounds, such as trimethylantimony, $Sb(CH_3)_3$, or antimony pentafluoride, SbF_5 .

49. The method of any of the claims 37-43 conducted for ion implanting in which the cleaning procedure is conducted for an ion source *in situ* in an ion implanter between changing ion source feed materials in order to implant a different ion species.

50. An ion implantation system having an ion source (400 or 10) and an extraction electrode (405 or 220) for extracting ions from said ion source, in which said electrode includes a heater constructed to maintain the electrode at an elevated temperature sufficient to substantially reduce condensation on said electrode of gases or vapors being ionized and products produced therefrom.

51. The system of claim 50 in which said electrode comprises aluminum.

52. The system of claim 50 in which said electrode comprises of molybdenum.

53. The system of claim 50, 51 or 52 in which said electrode is heated by radiative heaters (720, 730).

54. The system of claim 50, 51 or 52 in which said electrode is heated by resistive heaters (820).
55. The system of claim 53 or claim 54 in which the temperature of said electrode is controlled to a desired temperature.
56. The system of claim 55 in which said temperature is between 150C and 250C.
57. The system of any of the claims 50-56 in which said electrode is periodically cleaned by exposure to reactive halogen-containing gas.
58. A method of *in-situ* cleaning of an ion extraction electrode (405 or 220) of the system of any of the claims 1-36 or an ion extraction electrode (405 or 220) associated with an ion implanter, in which reactive halogen gas is flowed over the ion extraction electrode while said electrode is *in situ* and under vacuum.
59. The method of claim 58 where the reactive halogen gas is fluorine, F.
60. The method of claim 58 where the reactive halogen gas is chlorine, Cl.
61. The method of claim 59 in which the fluorine gas is introduced from a remote plasma source (455) into a vacuum housing in which said extraction electrode resides.
62. The method of claim 61 in which the fluorine gas is produced in the remote plasma source by a NF_3 plasma.
63. The method of claim 61 in which the fluorine gas is produced in the remote plasma source by a C_3F_8 or CF_4 plasma.
64. The method of claim 58 in which the reactive gas is ClF_3 .

65. The method of any of the claims 58-64 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized decaborane, $B_{10}H_{14}$.
66. The method of any of the claims 58-64 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized octadecaborane, $B_{18}H_{22}$.
67. The method of any of the claims 58-64 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized arsenic-containing compounds, such as arsine, AsH_3 , or elemental arsenic, As.
68. The method of any of the claims 58-64 in which the cleaning procedure is conducted to remove deposits after the ion source has ionized phosphorus-containing compounds, such as elemental phosphorus, P, or phosphine, PH_3 .
69. The method of any of the claims 58-64 conducted in conjunction with ion implanting in which the cleaning procedure is conducted between changing ion source feed materials in order to implant a different ion species.